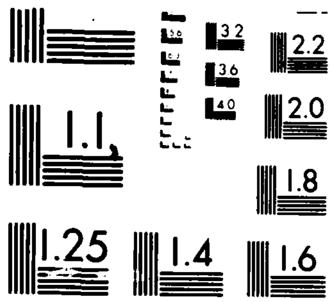
AD-A178 409 DIFFERENT GOALS OF INQUIRY TEACHING(U) BBN LABS INC CAMBRIDGE MA A COLLINS SEP 86 BBN-6458 N00014-85-C-0026 1/1

UNCLASSIFIED F/G 5/10 NL



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Report No. 6458

Different Goals of Inquiry Teaching

Technical Report

Allan Collins

September 1986

Approved for publication; distribution unlimited

A178409

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) BBN Report No. 6458	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION BBN Laboratories Incorporated 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION Personnel and Training Research Programs Office of Naval Research (Code 1142PT)
6c. ADDRESS (City, State, and ZIP Code) 10 Moulton Street Cambridge, MA 02238	7b. ADDRESS (City, State, and ZIP Code) 800 North Quincy Street Arlington, VA 22217-5000
8a. NAME OF FUNDING/SPONSORING ORGANIZATION 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER N00014-85-C-0026
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO	PROJECT NO	TASK NO	WORK UNIT ACCESSION NO
61153N	RR04206	RR04206-0A	NR 667-540

11. TITLE (Include Security Classification)
Different Goals of Inquiry Teaching (Unclassified)

12. PERSONAL AUTHOR(S)
Allan Collins

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Technical Report	FROM 1/1/86 TO 12/31/86	1986, September	12

16. SUPPLEMENTARY NOTATION
Questioning Exchange, Vol. 1, in press.

17. COSATI CODES		
FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Education, ~~Teaching~~, Metacognition, Thinking
[illegible]

19. ABSTRACT (Continue on reverse if necessary and identify by block number)
Among teachers who use inquiry methods, there are three distinct goals of their teaching. Some use inquiry methods to help students construct a theory or set of principles that is the teacher's own understanding of the domain. A second group of teachers use inquiry methods to help students construct genuinely novel theories or principles that emerge from the dialogue. A third group of teachers use inquiry methods to teach students how to ask themselves questions in order to teach "metacognitive" or self-monitoring skills. This paper describes teachers who pursue these different goals and how they use inquiry methods to do so.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL Dr. Susan Chipman	22b. TELEPHONE (Include Area Code) 202-696-4318 22c. OFFICE SYMBOL ONR 1142PT

Different Goals of Inquiry Teaching

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Abstract

Among inquiry teachers. there are three distinct goals of their teaching. One group uses inquiry methods to help students construct a given theory or set of principles. A second group uses inquiry methods to help students construct genuinely novel theories or principles. A third group uses inquiry methods to teach students how to pose questions themselves in order to teach self-monitoring skills. The paper describes and gives examples of teachers who pursue these different goals.

Different Goals of Inquiry Teaching

Allan Collins

Inquiry teaching forces students to actively engage in articulating theories and principles that are critical to deep understanding of a domain. The knowledge acquired is not simply content, it is content that can be employed in solving problems and making predictions. That is, inquiry teaching engages the student in using knowledge, so that it does not become "inert" knowledge like much of the wisdom received from books and lectures.

Among the teachers we have analyzed who use inquiry methods (Collins, 1977; Collins, Brown & Newman, in press; Collins & Stevens, 1982, 1983), we have identified three distinct goals of their teaching. Some use inquiry methods to help students construct a theory or set of principles that is the teacher's own understanding of the domain. A second group of teachers uses inquiry methods to help students construct genuinely novel theories or principles that emerge from the dialogue. A third group of teachers uses inquiry methods to teach students how to ask themselves questions in order to teach "metacognitive" or self-monitoring skills. In this paper, we will describe teachers who pursue these different goals and how they use inquiry methods to do so.

Teaching Principles or Theories

The most common goal of inquiry teachers is to force students to construct a particular principle or theory that the teacher has in mind. To accomplish this, they pose problems or cases to students, and ask them to try to formulate general rules or theories that lead to the correct answers in a variety of problems.

For example, Max Beberman, a famous math teacher we studied (Collins & Stevens, 1982), tried to get students to induce the rules for addition of real numbers by having students draw a line to the right on graph paper for each positive number and a line to the left for each negative number. Students quickly started using a shortcut: they added the positive numbers together, the negative numbers together and took the difference. They learned a generalized procedure for adding real numbers. Later Beberman tried to get the students to formulate the rules for addition of real numbers, as shown in Table 1.

Similarly in geography, as shown in Table 2, Richard Anderson (Collins, 1977) questioned a student about the relative temperatures in different places in North America to force the student to formulate and test the hypothesis that the average temperature of a place depends not just on the latitude, but also on the distance from the ocean (it also depends on other factors, such as altitude, but these were not discussed). In our analysis (Collins 1977, Collins & Stevens 1982), we characterized the questioning strategies teachers use in such dialogues in terms of production

Table 1

Excerpt from a Beberman dialogue
(annotated with strategies used in parenthesis)

T. I want to state a rule here which would tell somebody how to add negative numbers if they didn't know how to do it before. Christine? (Ask for rule formulation.)

S. The absolute value-well-*a* plus *b* equals uh-negative-

T. Yes, what do we do when we try to do a problem like that? Christine is on the right track. (Reward rule formulation.) What do you actually do? Go ahead, Christine. (Ask for rule formulation.)

S. You add the numbers of arithmetic 5 and 7, and then you-

T. I add the numbers of arithmetic 5 and 7: but how do I get the numbers of arithmetic when I'm talking with pronumerals like this? (Ask for generalization of factors.)

S. Well, you can substitute.

T. But I don't want to talk about any special cases: I want to talk about all the cases at once. (Ask for generalization of factors.)

Table 2

Two production rules in the theory with examples from an Anderson dialogue

Ask for relevant factors

If (1) there are either necessary or sufficient factors that have not been identified,

then (2) ask the student for any relevant factors.

Example. (From Anderson, in Collins, 1977)

T. Which is likely to have the coldest winter days, Newfoundland or Montana? (Entrapment into prediction based on insufficient factors--in this case a secondary factor overrides a primary factor.)

S. Newfoundland.

T. Please give your reasons for answering Newfoundland. (Ask for relevant factors.)

Ask for the formulation of a rule

If (1) one or more factors have been identified.

then (2) ask how the values of the factors are related to the value of the dependent variable.

Example. (from Anderson, in Collins, 1977)

T. Please try to be more precise (e.g., with respect to the effect of latitude on temperature). Would you, for instance, say that if you take any two places in the Northern Hemisphere, the one furthest south has the colder winter temperatures? (Suggest the formulation of a rule.)

S. No I wouln't say that.

T. What would you say? (Ask for the formulation of a rule.)

rules of the form. "If in situation x, ask question y." Examples of two of these production rules, together with excerpts from the Anderson dialogue are shown in Table 2.

This kind of inquiry is very effective at getting students to construct theories that can be used to make predictions. It even models for the students the kinds of questioning strategies scientists use to investigate a problem. The students participate in a kind of guided discovery of principles and theories. But the students know they are only rediscovering old principles, and that the teacher is withholding information in the dialogue. In this sense, it is only a variation on the strategy of questioning students to see what they know. Furthermore, without practicing the questioning strategies themselves, it is unlikely students will learn how to ask themselves the kinds of questions the teacher is asking. So this kind of inquiry dialogue goes some way toward teaching students how to use their knowledge to solve novel problems, but falls short of an ideal teaching strategy.

Teaching Theory Construction

Two teachers we studied (Collins & Stevens, 1982, 1983) clearly had a different goal in their questioning: they were trying to teach students how to construct novel principles or theories on their own. They had no prior theory they were trying to teach: only a set of constraints that a suitable principle or theory must meet.

One of these teachers, Eloise Warman, (Collins & Stevens, 1982) was teaching preschoolers principles of moral education. In one of the teaching sessions we analyzed, the problem had arisen among the children that the boys were monopolizing the blocks and the girls were not getting a chance to play with them. So Warman asked the children to discuss what would be a fair rule that would allow the girls to play with the blocks. The resolution of the problem is shown in Table 3. When the children asked her to suggest a rule, she refused, saying she had tried and that they had to come up with a fair rule themselves. After much discussion, when one of the boys suggested letting the girls play with the blocks on two days, she reformulated this into a new rule that the boys could play with blocks on two days and the girls on two days each week, and asked if that was fair. Thus, she was getting the children to think about how different principles of assigning toys promoted fairness.

The other teacher we analyzed (Collins & Stevens, 1982) who emphasized theory construction was Professor Roger Schank in teaching Artificial Intelligence. In the class we analyzed, the stated goal was to have the students construct a taxonomy of possible kinds of plans. Typically, Schank encourages students to construct theories that consist of a set of primitive elements, like the chemical elements. Thus, he wanted a theory of everyday plans, that consisted of the basic plan types from which all possible, more complex plans can be created. When students

Table 3

Excerpt from a Warman Dialogue (G=girl, B=boy)

T.	Do you think it should be all right that only one person should get to make all the choices for who gets to play with blocks? Or do you think it should be something we all decide on? (Ask for questioning of authority.)
G.	I think it should be the teachers.
T.	But why just the teachers? (Ask for questioning of authority.) It doesn't seem to work. We had an idea. We've been trying. (Point out insufficiency of factors in rule.)
B.	I've got one idea.
T.	Oh, Gregg's got a good idea. (Reward rule formulation.)
B.	The girls can play with the big blocks only on 2 days.
T.	Hey, listen we come to school 4 days a week. If the girls play with the big blocks on 2 days that gives the boys 2 other days to play with blocks. Does that sound fair? (Restate rule. Ask if rule is correct or incorrect--i.e., fair or not.)
G.	Yea! Yea!

suggested plan types that were in his book. Schank objected, telling them they had to come up with a different set of plan types, not the same one he had constructed. His emphasis was on creating a novel theory, not one that he knew in advance. His role was that of a moderator: to set the general goals, to write down the different suggestions, to get students to critique different solutions, to try to find redundancies or difficulties with the proposed typology, etc. This was a first course in Artificial Intelligence: in later courses and research, the students were coached in setting their own goals and critiquing their own solutions.

This kind of inquiry teaching emphasizes certain skills that the previous technique does not. In particular, it teaches students how to pose problems that can be solved, how to critique possible solutions, and how to recognize an acceptable solution when it has been found. The process is more like scientific or artistic problem solving in the real world. The teacher does not know what will be discovered: hence, he or she can exploit whatever ideas arise in the discussion. The teacher can even act as a participant in idea creation or synthesis: the goal is to come up with the best possible solution to a stated problem. In addition, the students perceive that something genuinely novel is being constructed by the process: that they are participants in real problem solving.

Teaching Self-Questioning Skills

Another group of teachers we analyzed (Collins, Brown, & Newman, in press) went beyond modelling question asking for students, to coaching students in actually posing questions themselves. Thus they used inquiry methods to teach students self-monitoring or "metacognitive" skills. Their general method of teaching we call "cognitive apprenticeship" (Collins, Brown, & Newman, in press).

One example is the Reciprocal Teaching method developed by Palincsar and Brown (1984) for teaching reading to elementary school students. The basic method centers on modelling and coaching students in two strategic skills: asking questions about a text and summarizing the text. A series of sessions with a poorer student on asking questions is shown in Table 4. It is called Reciprocal Teaching because the teacher and students take turns playing the role of teacher. At the beginning of the session, both the teacher and students read a paragraph silently to themselves. Whoever is playing the role of teacher formulates a question about the paragraph, constructs a summary, and makes a prediction or clarification if any come to mind. Initially, the teacher models this process, but then each student takes a turn. When students first undertake the process, the teacher coaches them extensively on how to construct good questions and summaries, offering prompts and critiquing their efforts. In this way, the teacher provides scaffolding for the students, enabling them to take on whatever portion of the task they can. As the students become more proficient, the teacher turns over more of the task to them. Formulating questions and

Table 4

The Acquisition of Question-Asking by a Weak Seventh-Grade Student Using Reciprocal Teaching (from Palincsar & Brown, 1984)

Day 1:

TEXT: The water moccasin, somewhat longer than the copperhead, is found in southeastern states. It lives in swampy regions. It belongs, as do also the copperhead and the rattlesnakes, to a group of poinsonous snakes called pit vipers. They have pits between their eyes and their nostrils which, because they are sensitive to heat, help the snakes tell them when they are near a warm-blooded animal. Another name for the water moccasin is "cottonmouth." This name comes from the white lining of the snake's mouth.

1. C: What is found in the southeastern snakes, also the copperhead, rattlesnakes, vipers--they have. I'm not doing this right.

2. T: All right. Do you want to know about pit vipers?

3. C: Yeah\

4. T: What would be a good question about the pit vipers that starts with the word "why?"

5. C: (no response)

6. T: How about, "Why are the snakes called pit vipers?"

7. C: Why do they want to know that they are called pit vipers?

8. T: Try it again.

9. C: Why do they, pit vipers in a pit?

10. T: How about, "Why do they call the snakes pit vipers?"

11. C: Why do they call the snakes pit vipers?

12. T: There you go! Good for you.

Day 4:

TEXT: Spinner's mate is much smaller than she, and his body is dull brown. He spends most of his time sitting at one side of her web.

13. C: (No question)

14. T: What's this paragraph about?

15. C: Spinner's mate. How do spinner's mate...

16. T: That's good. Keep going.

17. C: How do spinner's mate is smaller than...How am I going to say that?

18. T: Take your time with it. You want to ask a question about spinner's mate and what he does, beginning with the word "how."

19. C: How do they spend most of his time sitting?

20. T: You're very close. The question would be, "How does spinner's mate spend most of his time?" Now, you ask it.

21. C: How does spinner's mate spend most of his time?

Day 7:

TEXT: Perhaps you are wondering where the lava and other volcanic products come from. Deep within our earth there are pockets of molten rock called magma. Forced upward in part by gas pressure, this molten rock continually tries to reach the surface. Eventually--by means of cracks in the crustal rocks or some similar zone of weakness--the magma may break out of the ground. It then flows from the vent as lava, or spews skyward as dense clouds of lava particles.

22. C: How does the pressure from below pushes the mass of hot rock against the opening? Is that it?

23. T: Not quite. Start your question with, "What happens when?"

24. C: What happens when the pressure from below pushes the mass of hot rock against the opening?

25. T: Good for you! Good job.

Day 11:

TEXT: One of the most interesting of the insect-eating plants is the Venus's flytrap. This plant lives in only one small area of the world--the coastal marshes of North and South Carolina. The Venus's flytrap doesn't look unusual. Its habits, however, make it truly a plant wonder.

26. C: What is the most interesting of the insect eating plants, and where do the plants live at?

27. T: Two excellent questions! They are both clear and important questions. Ask us one at a time now.

Day 15:

TEXT: Scientists also come to the South Pole to study the strange lights that glow overhead during the Antarctic night. (It's a cold and lonely world for the few hardy people who "winter over" the polar night.) These "southern lights" are caused by the Earth acting like a magnet on electrical particles in the air. They are clues that may help us understand the Earth's core and the upper edges of its blanket of air.

28. C: Why do scientists come to the south pole to study?

29. T: Excellent question! That is what this paragraph is all about.

summarizing are important strategies for self-monitoring because they provide a basis for self-diagnosis: If you cannot formulate a question or summarize a passage, then you do not understand it. By getting students to critique other students' questions and summaries, it forces them to articulate why some questions or summaries are central to the passage and others not.

As a second example, Professor Alan Schoenfeld (1983, 1985) tried to teach self-monitoring strategies for solving mathematics problems to college students. His approach was first to model for the students how to use different problem solving techniques (called heuristics). Then he would give the class problems to solve that involved the same heuristic. Like Schank, he would serve as moderator, soliciting possible solution techniques from the students, getting them to evaluate which techniques are most likely to work, asking them to evaluate their progress as they proceeded. Then he would have the students break up into groups to solve problems, and he would go from group to group acting as a consultant. Typically he asked them three questions: (1) what they are doing, (2) why they are doing it, and (3) how success in what they are doing would help them solve the problem. As the course proceeded, students came to anticipate his questions by asking the questions of themselves. In this way he turned the monitoring that he exercised in the class as a whole over to the students themselves.

Self questioning is critical to monitoring your understanding and your progress in problem solving. Palincsar and Brown, and Schoenfeld both focus on teaching students how to do self questioning. This is a twist on the usual inquiry teaching model where the teacher asks all the questions. Here, the teacher starts out asking questions, but then tries to turn the questioning over to the students, providing whatever scaffolding the students need to take over the role of questioning. This kind of teaching is directly aimed at teaching students critical inquiry skills.

Conclusion

Inquiry teaching should be thought of as one of the teaching methods that the successful teacher interweaves with other methods. We think of it as a tool to be used within a more general "cognitive apprenticeship" (Collins, Brown, & Newman, in press) where it plays two distinct roles: (1) to force students to articulate their knowledge as strategies, principles, and theories that they can call upon in different contexts and (2) to teach students questioning skills so that they can learn new domains or solve novel problems on their own.

Inquiry teaching fits naturally into a more general philosophy of teaching knowledge in situated contexts. Learning theories is not enough: one must learn when and how to use them, e.g., how to make predictions, construct and test hypotheses, etc. Too much of education is taught as abstract content, rather than usable knowledge.

Furthermore, skill in question asking and problem finding (Getzels & Csikszentmihalyi, 1976; Scardamalia & Bereiter, 1985) is critical to all problem solving in science and the arts. We suspect these are the most critical skills students can learn during their schooling, and that students vary widely in their native ability. But if students can practice the skills of asking questions and posing problems for themselves under the apprenticeship of a skilled teacher, then we think they can learn these critical skills.

Acknowledgements

This research was supported by the National Institute of Education under Contract No. US-NIE-C-400-81-0030 and by the Office of Naval Research under Contract No. N00014-C-85-0026. I thank Amy Aaronson, Arthur Graesser, and Kathryn Crawford for their comments.

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